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A GUIDE TO BITTERBRUSH SEEDING IN CALIFORNIA

Richard L. Hubbard

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In 1952 the Ca Game entered into a cooperative a /est Forest and Range Experiment S S. Department of Agriculture, to d e ways and means of re-establishing browse vegetation on the Great Basin type ranges of eastern California. It was financed under the Federal Aid to Wildlife Restoration Act--Project W-52-R, "Big Game Investigations."

The objectives of the research have been fulfilled. This bulletin contains guides for successfully seeding bitterbrush (Purshia tridentata), the most adaptable species found, on deer winter ranges throughout northeastern California. The large amount of technical information developed by this project has been published currently as the research and extensive field trials of research results have progressed. Practical aspects of the findings are set out here for application in the improvement and management of California's deer winter ranges.

John R. McGuire, Director
Pacific Southwest Forest and Range
Experiment Station, Forest Service
U. S. Department of Agriculture

Walter T. Shannon, Director
California Department of Fish and Game

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WHY ARE WE INTERESTED?

Deer must eat. Unfortunately, there is not always enough food of good quality for all of them, and many die of malnutrition each year, particularly during severe winters. This lack of food is possibly a three-pronged problem. First, deer numbers tend to build up beyond the ability of the range to support them. Second, some of the food supply has been lost because of fire, overgrazing, plowing, and other causes--some natural, some caused by man. The third phase of the problem is what man can do to assist in rebuilding the food supply. Artificial seeding may be much faster than natural processes.

The first step towards balancing deer and their food supply is to reduce deer numbers. This is logical. If a rancher does not have enough hay for his cows, he either obtains more feed or reduces his herd. Game Departments throughout the West have long recommended the orderly removal of excess animals. These recommendations aim at maintenance of healthy, well-managed deer herds, and reduction of grazing damage and loss of important food plants.

The second step is to evaluate the overall use on the range by both deer and livestock. Deer are only one of the contributing factors leading to range deterioration. In most cases, damage to browse plants is from combined use by deer, cattle, or sheep, although each kind of animal is capable of damaging the plants without help from the others. Grazing damage by livestock can be controlled by reducing the number allowed; by changing the season of grazing; or by improving distribution through salting, watering, or fencing. Deer are not as easily handled as livestock, and reduction of numbers by hunting is about the only tool available. It can be an effective tool if used properly.

Even though excessive grazing, fire, or other causes of loss are stopped, this is seldom the whole answer. When fire kills food plants, it takes many years for the desirable browse to come back naturally on these ranges. When farmers plow up and then abandon deer ranges these, too, take many years to return to browse. And overgrazing keeps young plants from coming in to replace those which die; consequently, even if overgrazed ranges were given complete protection immediately, it would be too late to save some of them because less desirable plants have taken over.

Artificial reseeding speeds up the recuperation of these ranges and although expensive, this step in balancing deer numbers and food supply may pay off much more than leaving the land to many years of unproductiveness.

WHY PLANT BITTERBRUSH?

To qualify as good deer feed, a plant species must be palatable, highly nutritious, and well able to withstand grazing. It must remain within reach of the deer, ruling out species which develop into small trees. Since the present shortage of deer feed is largely on winter ranges, selected species must grow well under the dry, semi-desert conditions typical of most winter ranges in California on the east side of the Sierra Nevada crest.

At the start of browse reseeding studies, we looked for some exotic, miracle plant which had all of these qualities plus a few more. So far, such a plant has not been found. Native plants such as bitterbrush, fourwing saltbush (Atriplex canescens), and wedgeleaf ceanothus (Ceanothus cuneatus) have shown the most promise. Bitterbrush is best suited to the critical deer winter ranges on the east side of the Sierra Nevada. Saltbush grows on lower and somewhat drier sites, and wedgeleaf ceanothus in areas of higher rainfall, than are usually found on eastside winter ranges. Both species can be planted and will grow on the critical ranges but bitterbrush grows on these ranges naturally and is at least as palatable and nutritious as the other two. Bitterbrush also withstands grazing well.

Before leaving the question of what to plant, let us look at the place of grass reseeding in game habitat improvement. At one time, it was thought that grass was not an important deer food. Leach (1956) and others, however, have reported that California deer eat large amounts of grass during the winter and early spring. Grass will grow better than browse on some parts of the winter range and the logical thing to plant here, of course, is grass.

Planting alternate strips of grass and bitterbrush provides more "edge" which is biologically important and makes the area less vulnerable to wildfire. In southern California, planting strips of grass in brush fields is the underlying principle of the fuel-break program being recommended for reducing the fire hazard. Planting a mixture of brush and grass seed, however, is not recommended because the brush and grass compete directly for moisture. Grasses are only available to deer when there is no snow and, therefore, the main emphasis on game range revegetation is placed on browse.

SEED COLLECTION AND HANDLING

Collecting the Seed

Bitterbrush seed is not yet commercially available in large quantities from local sources. Some seed collectors and distributors are beginning to stock small quantities. Generally, the best way to obtain seed is to collect it yourself or contract to have it collected.

Proper timing of the collection is most critical. The seed falls naturally soon after it ripens, and a windstorm may blow the seed off

in a day or so. Because of the short collection period, seed development must be followed closely. Therefore, we must understand something about the seed itself; how it ripens and how to forecast collection time.

The fruit of bitterbrush is an achene with a leathery, slightly grooved, fine hairy husk (fig. 1). The seed looks something like an apple seed, about 1/4 to 3/8 inch long. Hormay (1943) reported that the seed coat contains a reddish purple sap which congeals into a hard granular mass when the seed is fully ripe. Seed ripeness should be checked every few days once this purplish sap starts to thicken. The seed is ripe when it falls readily with gentle shaking of the bushes.

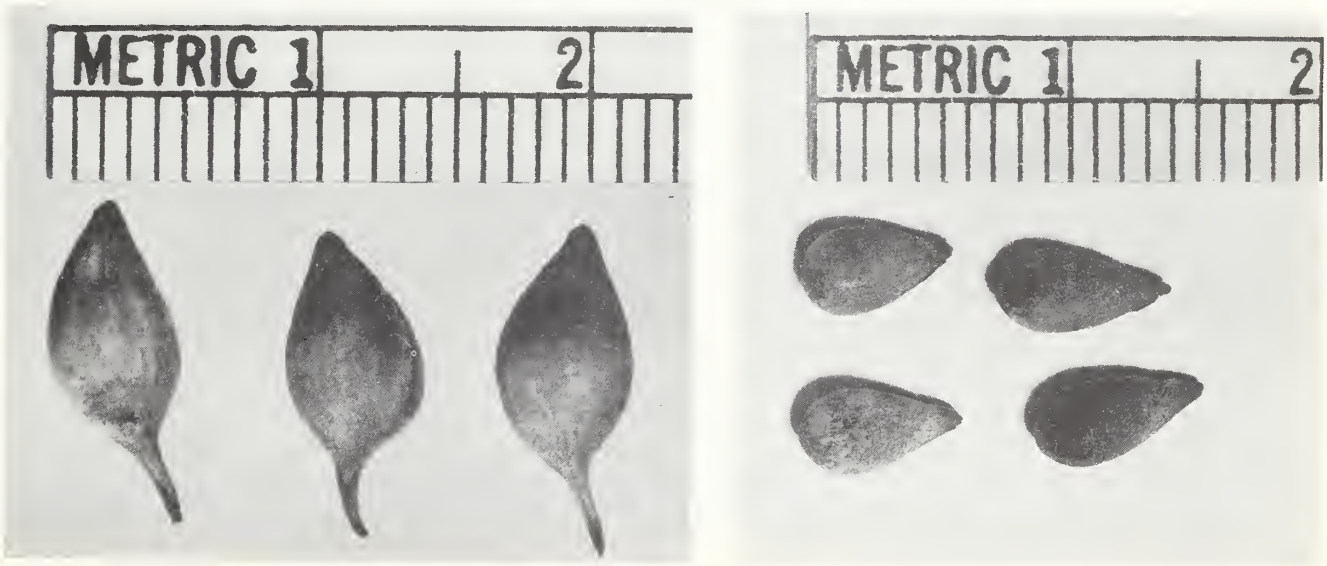

Figure 1. --Bitterbrush fruit, left, and a husked seed, right.

Tools for collecting are simple and cheap: only a tray to catch seed and a stick or paddle to beat the bushes. Cardboard trays cut from packing boxes are satisfactory. They should be about 6 inches deep and as large as can be handled comfortably. The larger the tray, the less seed lost on the ground. Hugo Hermann, California Department of Fish and Game, has designed a tray, made from a 30 x 36-inch window screen and equipped with sideboards, which is a decided improvement over those made of cardboard (fig. 2). A handle above and in the middle of the screen is attached by wires to the frame. It is light and easily maneuvered and the screened bottom allows much of the smaller trash to fall out. Spreading canvas under a bush recovers a larger percentage of the seed from individual bushes than does collection with trays but consumes too much time moving from bush to bush.

The Arcadia Equipment Development Center, U. S. Forest Service, is working on a mechanical seed collector which is essentially

a big vacuum cleaner. When operational this machine may help reduce the cost of collecting bitterbrush seed.

Figure 2. --A 30 x 36-inch window screen tray equipped with sideboards. Designed by Hugo Hermann, California Department of Fish and Game.

Checking Seed Quality

Always check seed quality before collecting. Sometimes nearly all the fruit produced in a particular bitterbrush stand contains blackened, shriveled, nonviable seeds. Viable bitterbrush seed is plump and grayish and contains a white embryo (fig. 3). To check for good seed, rub a sample of fruits between your hands to break the husks. Blow away the chaff, then smash each seed with a hammer. If white shows prominently, the seed contains a healthy embryo and is probably viable.

Cleaning the Seed

Large quantities of seed can be cleaned by machines which accomplish the same process used in hand rubbing and blowing to check seed quality. The husk must first be broken and then the chaff removed by winnowing. Care must be taken not to damage the tip, or radical end,

of the seed while removing the husk. Several machines can be used for this job. A hammermill operated at slow speed does the dehusking with minimum damage. The operating speed of the hammer should not exceed 37 feet per second on the outer edge of the hammer swing. Thus, a hammermill with a 13-inch diameter swing should operate at 650 rpm. Several types of pine-seed dewinging machines do a very satisfactory job. Standard grain cleaners do a good job of removing the chaff and light unfilled seed after dehusking.

Figure 3. --Healthy, plump, viable bitterbrush seed, left, and blackened, shriveled, non-viable bitterbrush seed, right.

Many commercial seed processors are equipped to do the cleaning, and contracting is probably the cheapest way of getting the seed processing done.

Storing the Seed

Storage in airtight containers in a dry room at about 41° F., as recommended by Hormay (1943) is ideal. However, Holmgren and Basile (1959) reported no appreciable reduction in germination after 7 years' storage in a dry, unheated room. Our experience has shown that the most important requirement of storage is keeping the seed dry.

Breaking Seed Dormancy

Bitterbrush seed has a dormancy which may prevent germination without treatment. Dormancy is broken in nature when seed overwinters in the soil. Seed planted in the fall, therefore, needs no treatment. But if seed is planted in the spring, usually recommended under California conditions, it must be treated artificially. Simulating the natural overwintering process is one method of breaking dormancy. This requires that the seed be kept moist, aerated, and cold--between

32° and 41° F. This treatment is called cold stratification and works for many species having seed dormancy. Its main drawback is that the seed must be kept moist until planted. Moist bitterbrush seed is soft and easily damaged so that machine planting is impossible.

A better method of breaking seed dormancy consists of soaking the seed in a 3-percent solution of thiourea for 3 to 5 minutes. Thiourea can be obtained from most chemical supply houses. The treatment procedure we have found simplest is to:

1. Use a 30-gallon container. Mix 3 pounds of thiourea with 2 gallons (15 pounds) of hot water.

2. Stir the mixture until the thiourea is completely dissolved.

3. Add 12 gallons (85 pounds) of cold tap water. This makes enough solution to treat 30 pounds of bitterbrush seed.

4. Pour the seed into the solution and stir until all the seed sinks (fig. 4). Soak for 5 minutes, stirring occasionally.

5. Pour the solution and seed onto a screen. After it drains, spread the seed in a 1-inch layer on canvas to dry. The seed will dry in 2 or 3 days and then can be planted by mechanical seeders without damage.

Be careful not to add the seed to a solution warmer than 70° F., which means cool to the touch. Brown and Martinsen (1959) reported that warmer solutions reduced germination and caused deformed seedlings. Do not store treated seed longer than 6 months.

Occasionally, seed from a certain source may need more than 5 minutes' soaking, but this is rare. It is always wise, though, to test germination of the seed after treatment. A simple procedure is to place samples on moist germination blotters in petri dishes. The results are available in a few days (fig. 5). It is good insurance against planting nonviable seed.

WHERE TO PLANT

Where to plant is actually two questions. First, where do we need to plant and, second, where is it possible to plant? The answer to the first part of the question is that the winter range usually needs it most. Each winter range is different.

Bitterbrush makes its best development on coarse-textured, well drained, rapidly permeable soils having a slightly acid reaction (pH 6.0 to 7.0) and a depth of 5 feet or more.

Figure 4. --Treating bitterbrush seed with thiourea is a quick, easy, and effective method of breaking seed dormancy. Equipment used is easily obtainable.

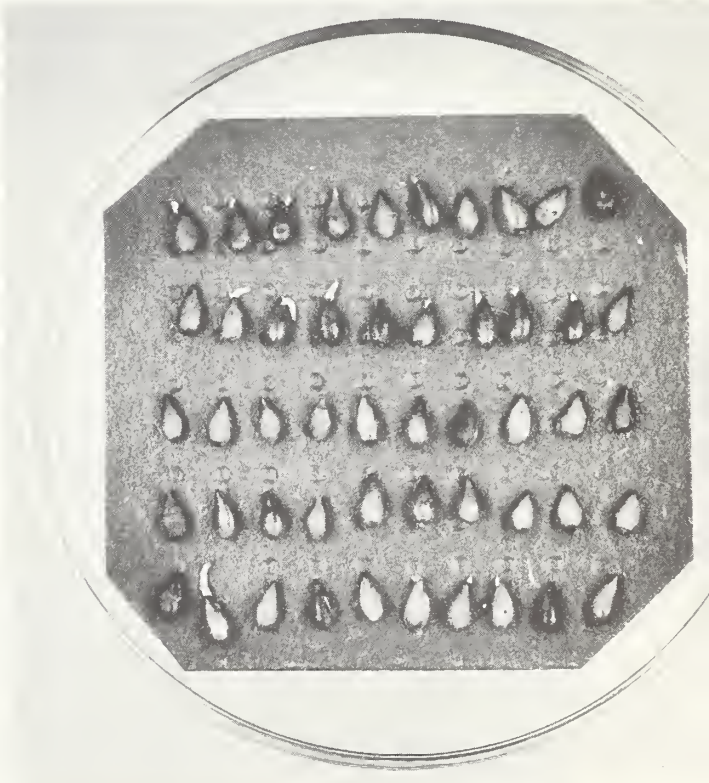

Figure 5. --Germination tests should always be made after treating an unfamiliar bitterbrush seed lot with thiourea.

Sometimes plantings are made on something less than the best soils because the decision on where to plant must take into account both need and feasibility. The soils on which bitterbrush makes its best development are not always the easiest to seed successfully. The coarse-textured soil required for the best development of bitterbrush loses its top-soil moisture rapidly. During dry springs, the rate of root penetration of new seedlings is slower than the rate of drying. In heavier soils, moisture is retained longer, and the seedlings stand a better chance. This is, of course, a matter of degree. Bitterbrush grows poorly or not at all on very heavy soils such as adobe.

Some of the other soil conditions are more restrictive. If there are signs that bitterbrush has grown on an area before, it is safe to assume that the soil is suitable for bitterbrush. If there are no signs of bitterbrush having grown on a site previously, the soil should be checked closely before planting. A hardpan within 3 feet of the surface rules out any area for bitterbrush planting. The presence of low sagebrush (Artemisia arbuscule) is a sign of restricted drainage in northeastern California.

The pH, or soil reaction, should always be checked. Nord (1949) reported that bitterbrush usually is not found on soils with a pH over 7.3.

Seed from areas similar or near to the planting site should be used if available. With further study, particular strains may prove best, but enough isn't known as yet to make any such recommendations.

HOW TO PLANT

Site Preparation

Site preparation has two purposes: To reduce the amount of competing vegetation and to provide a suitable seedbed.

Getting rid of vegetation which would compete directly with the young bitterbrush seedlings is one of the most important steps in the seeding job. Most browse plantings will be made on dry sites where competition for moisture is keen. Soil moisture will approach the wilting point as deep as 54 inches by August on dry sites under undisturbed, natural vegetation. Under severe competition, seedling mortality is high and the few seedlings that do survive are stunted (fig. 6). The more competing vegetation removed, the better the chance young seedlings have to survive.

The job of reducing or removing competing vegetation differs from area to area. In many parts of the West dense juniper and Pinyon pine stands must be removed before seeding browse species. This is usually done by cabling; that is, dragging a 150- to 300-foot, 1-1/2-inch cable in a U shape between two large crawler-type tractors, as A. P. Plummer and his colleagues recommended in USDA Handbook 71 in 1955.

Figure 6.--Bitterbrush shown in the picture was seeded nine years ago in two strips. Both were plowed before planting. The strip on the left was seeded with bitterbrush alone while the strip on the right was seeded with a mixture of bitterbrush and crested wheatgrass seed. Emergence on the grass strip was at least as good as on the other, but the young seedlings just could not compete successfully with the grass.

In Idaho, browse species are seeded on areas of loose, rock-free soil where cheatgrass is the main competitor (Holmgren and Basile, 1959). Site preparation and planting are done in one operation with a middle-buster plow and a single-row seeder (fig. 7). The plow scalps a 30-inch strip, and the seeder plants a row in the middle of the strip. Hand scalping and planting are used where the terrain is too steep for this machine.

The scalping and planting machine can be used to advantage in many California areas, but in many others either the ground is too rocky or perennial grass and brush are too heavy for satisfactory scalping.

On these sites, especially if large acreages are to be seeded, heavy duty range seeding equipment does the best job. The brushland plow (fig. 8), developed by the U. S. Forest Service for use on rough

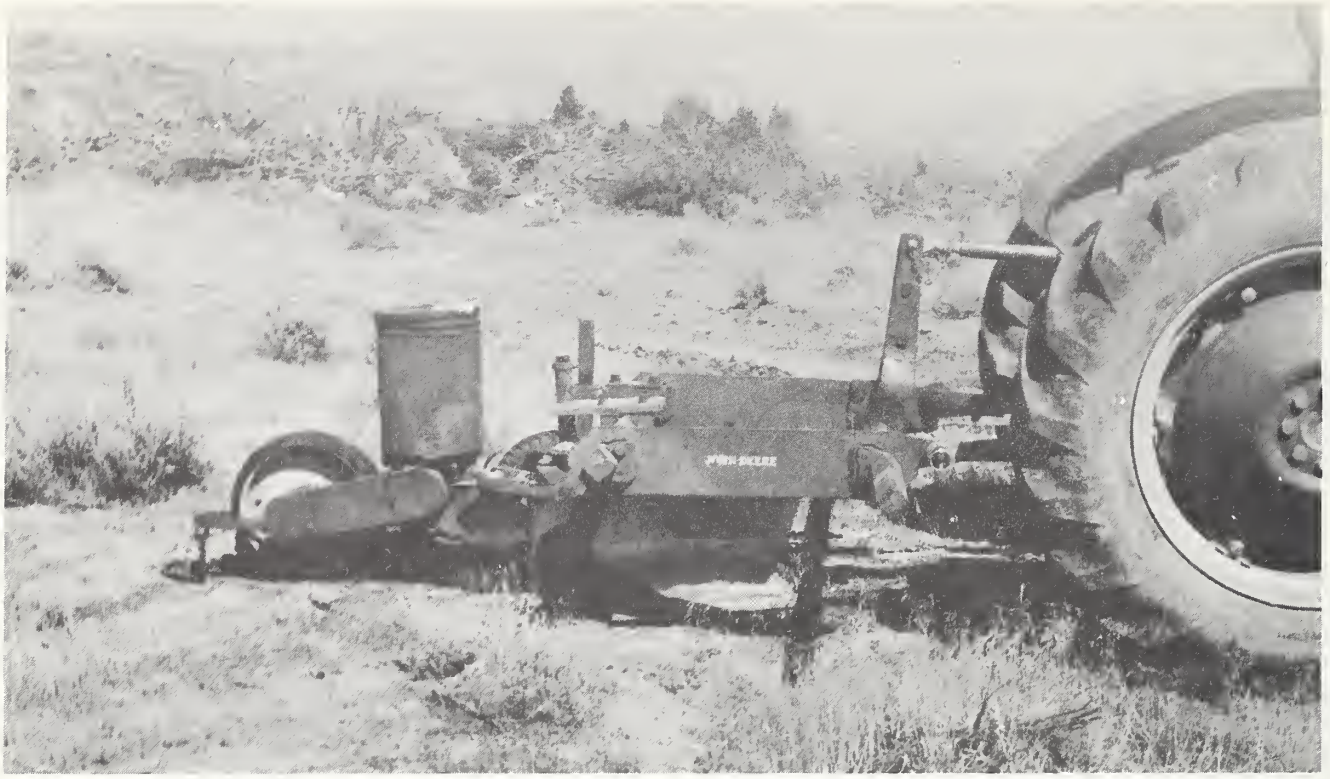

Figure 7. --The Idaho adaptation of the Flexi-planter used to remove cheatgrass competition and seed bitterbrush in one operation.

Figure 8. --The brushland plow was designed especially for rough rangeland conditions.

rangeland sites, has been the most satisfactory equipment used to date for plowing. It does a good job nearly anywhere that a crawler-type tractor can be operated. Heavy brush should either be burned or removed mechanically before plowing. The brushland plow can root out a fair amount of brush and still do a good job of plowing. But if the brush is heavy, the plowing will be trashy and difficult to seed. Also, turning under large quantities of brush forms air pockets, and as a result the soil dries rapidly.

After plowing, the soil is loose and somewhat uneven. It does not fulfill the requirement of a smooth, firm seedbed. Harrowing with three 10-foot sections of railroad iron, hooked one behind the other about 2 feet apart, smoothes the soil and firms it somewhat. A roller can be used, if further firming is necessary, for accurate control of planting depth (fig. 9).

Dragging and rolling right after plowing also reduces the loss of soil moisture. In dry years or on dry sites, this reduction in moisture loss can mean the difference between success and failure of spring plantings.

Depth of Planting

A rule of thumb for proper planting depth is: plant as shallow as possible without running the risk of the soil drying to that depth before the seedling roots have a chance to go deeper. This depth must, of course, be shallower than the maximum of about 2 inches from which bitterbrush seedlings can emerge.

A soil's drying rate depends upon weather and the capacity of the particular soil to hold moisture. Precipitation varies from year to year; so does optimum planting depth. Our recommendation is: plant about 1 inch deep on loam soils and 1-1/2-inches deep on lighter soils. These depths should give success in all but the driest years.

Planting Method

Objectives of any planting method are: to distribute the seed evenly; to place it at the proper depth; to cover it with soil; and to firm the soil over the seed.

Planting tools range from hand tools to fairly complicated machines. The rangeland drill (fig. 10), a machine developed by the Forest Service expressly for seeding rough rangelands, has done the best job in California. This drill is patterned after the fluted-feed type farm drill, but the disk openers on individual arms are capable of riding over obstructions 12 to 18 inches high. The large wheels make the drill easy to pull in rough, rocky country, and the frame is strong enough to minimize breakage. The rangeland drill will seed anywhere that the brushland plow can work.

One drawback to the rangeland drill, and all other fluted-feed drills, is that it cannot be adjusted to seed bitterbrush alone at the

Figure 9. --After plowing, dragging with sections of railroad iron, above, will smooth and firm the seedbed. If further firming is needed, rolling or cultipacking, below, will do the job.

Figure 10. --The rangeland drill--a companion piece to the brushland plow--is also designed for rough rangeland use. The drill shown here has the depth bands removed and is equipped with pipe drags for deep-furrow planting.

low rates normally used without damaging the seed. Therefore, the seed should be mixed with some bulk material. Rice hulls provide adequate bulk when mixed in a ratio of 8 pounds of hulls to 3 pounds of seed. Drill settings for various seeding rates can be determined from figure 11.

On sites with 12 inches or more precipitation, seeding about 3 pounds of viable seed per acre is usually satisfactory. Drier sites should be seeded heavier.

Seeding depth is controlled on the rangeland drill by depth bands and by adding weight to each disk opener. The depth bands, circular steel bands bolted to the disks to keep them from cutting too deeply, are used on soft, plowed seedbeds where too deep planting becomes a danger. In seeding unplowed seedbeds, as is sometimes done on burns, it is often difficult to get the seed deep enough. Then weights are added to make the disks cut deeper. These weights come with the drill and fit on a peg welded to each disk assembly.

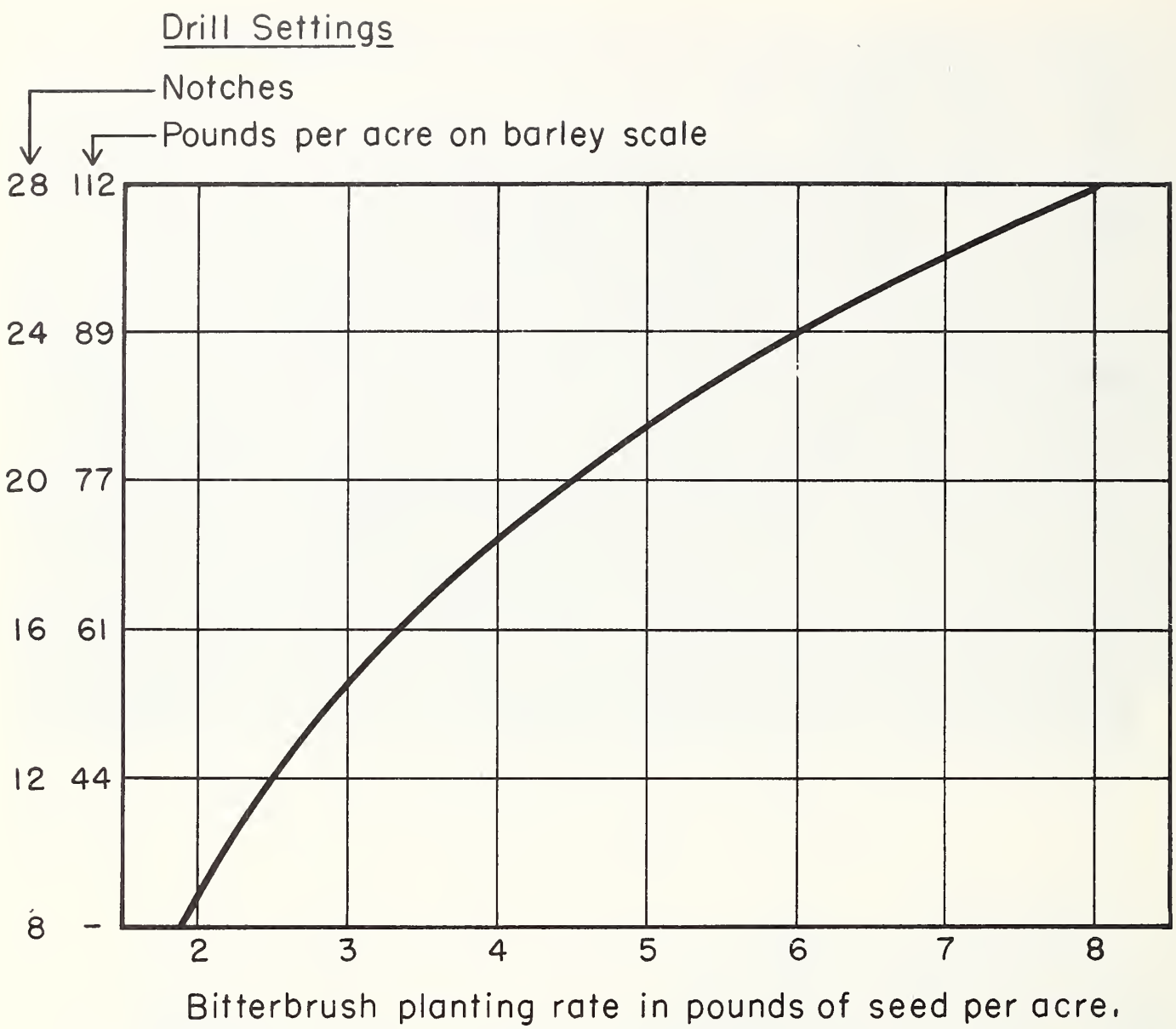

Figure 11. --Chart showing proper drill settings for seeding bitterbrush seed-rice hull mixture (from Nord and Knowles, 1958). These settings are based on 6-inch drill-row spacing. For other spacings, divide the distance in inches between drill rows and multiply the result times the notch setting shown on the chart for the desired seeding rate.

The drill is equipped with drag chains attached behind each disk to cover the seed. These chains are usually satisfactory, but on trash-free seedbeds a log chain dragged in a U shape behind the drill will do better. Press wheels, now being designed for the rangeland drill, may improve seed coverage and soil firming over the seed.

Firming the soil after planting is particularly important in spring planting to prevent loss of moisture. Since press wheels

have not been available, rollers and cultipackers have been used. Some rollers are designed for attachment to the rangeland drill. With these, drilling and packing can be done in one operation if the tractor has enough power to pull both.

Deep-furrow planting is sometimes successful with bitterbrush. It puts the seed down to moist soil and the furrows serve as moisture catchment basins. The seed is dropped in the 3- to 5-inch furrows and covered with 1 to 1-1/2 inches of soil. This can be done with the rangeland drill by removing the depth bands and weighting each disk enough to cut to the proper furrow depth. Enough soil sloughs from the sides of the furrows to cover the seed. Pipe drags attached behind each disk follow in the furrow and pack the soil at the bottom and sides. Deep-furrow planting should not be used where there is danger of wind filling the furrows with soil.

The Hansen furrower, a machine especially designed for deep-furrow planting, is used extensively in Utah following cabling of pinyon-juniper stands. Two 6-inch moldboard plows spaced 28 inches apart, open the furrows. The seed is dropped into the furrow through a tube from a 10-quart seed hopper. A rotating, circular, notched plate in the bottom of the hopper meters the seed. This machine is sturdily constructed and has been used satisfactorily in rocky areas. Since it weighs only 350 pounds, transport is easy; both wheel tractors and jeeps can pull it.

Idaho's unique adaptation of the Flexi-planter that cleans off competing vegetation and plants the seed in the same operation has already been mentioned. It also has a rotating, serrated plate in the bottom of the hopper which meters the seed into the planting tube. The rate of seeding can be changed by changing plates. A bar or chain drag behind the disk opener covers the seed. Press wheels firm the soil over the seed and provide the drive for the seeding mechanism. This tool is designed to seed relatively rock-free, light soils covered with cheatgrass. It is not sturdy enough for use on rocky sites.

A machine being developed under the auspices of the Range Equipment Seeding Committee[1] is intended to incorporate the best features of the Idaho and Utah machines. This type of machine is needed, especially in California. Much of northeastern California is lava country, and some of the lava rims are important winter deer range. Seedable areas in these rims are so small that the cost of moving the larger equipment makes seeding almost prohibitive. An easily transported machine which both clears a seedbed and plants is undoubtedly the answer. It would also be suitable for seeding areas covered by annual grasses and weeds.

Another machine which should not be overlooked is the ordinary farm drill. Most models can be used for seeding browse on even, rock-free sites. Relatively easy to obtain, these machines are

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[1] An interagency group devoted to design and improvement of all types of range seeding equipment.

designed for well-prepared seedbeds. On such areas it will do at least as good a job as any of the specialized range seeders.

Hand seeding also has a place in browse seeding. Hand plantings have been made in Idaho on slopes too steep for machinery. In California, many areas are suitable for machine planting. These should be planted first since machine seeding will generally buy more for the dollar.

WHEN TO PLANT--SPRING OR FALL?

Both spring and fall planting have advantages and disadvantages. In northern California, spring planting has produced 3 to 4 times as many seedlings per acre as fall planting. R. C. Holmgren and J. V. Basile, in Idaho, and E. R. Brown and C. F. Martinsen in Washington, reported in 1959 that fall planting has given by far the best results in these states.

Successful planting depends upon the soil remaining moist during the critical germination and emergence periods. Seedlings generally emerge earlier from fall plantings than from spring plantings because fall-planted seed is in the ground and ready to sprout as soon as the soil warms up in the spring. This means, then, that the critical period is later for spring planting than for fall planting. The soil must, therefore, remain moist longer for spring planting to work. Either adequate, well-distributed precipitation or high soil moisture retention--loam soils retain moisture well while coarse sands retain moisture for only a short while--can provide this longer moist period. Where either, or both, of these conditions are met, spring plantings are usually successful.

The earlier a plant emerges, the better chance it has to survive. Why, then, not take advantage of the earlier emergence from fall planting? We have found that where spring planting is applicable, the amount of emergence is enough greater to offset the advantages of earlier emergence. The reasons for the better emergence from spring planting are incompletely understood. Perhaps rodents have a better chance at fall-planted seed, both because of the longer storage in the ground and because seed is there before rodent numbers are reduced by winter conditions. Crusting of fairly heavy soil sometimes causes fall planting to fail, and frost action may replant fall-planted seed at an unsatisfactory depth.

Spring planting is best under California conditions if the annual precipitation is more than 12 inches and well distributed in the spring and if the soil is a sandy loam or heavier. We do not recommend spring planting on sites which have only a very brief period with adequate moisture at the seed level. On such areas fall planting is the only possibility.

ANIMAL PESTS AND WAYS TO COMBAT THEM

Rodents

Rodents are nature's planters. They bury bitterbrush seed as it ripens, according to A. L. Hormay, intending to dig the seed up later for food. Sometimes they bury more than they need, and the surplus germinates if growing conditions permit. When we plant the seed, rodents are largely detrimental because they dig up the planted seed.

Rodents frequently cause the failure of bitterbrush plantings in both Idaho and Washington. Holmgren and Basile (1959), Brown and Martinsen (1959), and Casebeer (1954) found that rodents dug up much of the bitterbrush seed planted in these States. But in California no failures have yet been traced to rodents.

Why is this? Perhaps because most California plantings have been drilled. Consequently, the seed was not placed in isolated spots or rows as in Idaho and Washington but, instead, was distributed evenly over the planting area. Also, most California plantings have been spring plantings, whereas most in Idaho and Washington have been fall plantings. It may be, too, that availability of rodent food more palatable than bitterbrush is a factor. Most areas seeded in California have a variety of rodent foods; on many of Idaho's winter-spring ranges, cheatgrass is almost the only vegetation.

This does not mean that rodents won't become a problem in California. Consequently, treatments that protect the seed from rodents are cheap insurance. The Denver Wildlife Research Laboratory, U. S. Fish and Wildlife Service has developed treatments that appear successful. Where a need for protection from rodents develops, the local representative of the U. S. Fish and Wildlife Service should be consulted.

Combining thiourea and protective treatments will reduce the germination of some bitterbrush seed lots. Unknown seed lots so treated should be tested for germination.

Meadow mice (Microtus montanus) will occasionally damage reseeded bitterbrush stands by girdling the plants. This sort of damage occurred near Hallelujah Junction, California, in 1957 and 1958 when the meadow mouse population was extremely high through northeastern California. The mice moved into the sagebrush-bitterbrush type where bitterbrush seeding had been done. Their migration was unusual. This type is far from an ideal habitat for meadow mice, which usually occupy areas densely covered with grass and herbaceous vegetation. It is only when a population irruption of these mice occurs that they move into marginal areas such as this and damage bitterbrush.

Jackrabbits

Damage by jackrabbits (Lepus californicus) has been one of the biggest problems on bitterbrush seedings in northeastern California. Generally, they do not kill the seedlings outright because they turn to them fairly late in the fall when some use can be tolerated. However, 3 or 4 years of heavy jackrabbit use may kill the plants. The rabbits prefer the succulent tips. If use is not too heavy, the plants will produce large branches by the third or fourth year and probably grow out of danger unless the jackrabbit population builds up to a very high level.

On one 1960 spring planting, damage began much earlier in the summer than usual. The plants were still too small to withstand any grazing, and only 10 percent survived. Inside a jackrabbit exclosure, 76 percent survived. The year was very dry, and very little vegetation except the bitterbrush seedlings was still green by the middle of July. This may explain the early use.

Jackrabbit use depends upon two things--the number of rabbits and the availability of palatable food other than bitterbrush seedlings. There is some evidence that bitterbrush is only moderately palatable to jackrabbits. They generally use hopsage (Grayia spinosa), desert peach (Prunus andersonii), big sagebrush (Artemisia tridentata), and fourwing saltbush (Atriplex canescens) more heavily then bitterbrush.

More likely solutions are to control jackrabbit numbers or to predict the occurrence of natural low populations when plantings would be most safe. No effective control measure has yet been developed. If direct control was possible, it would probably be the best solution to the problem of damage by jackrabbits.

Grazing Animals

Deer, cattle, and sheep all damage young, seeded bitterbrush plants at times--and in essentially the same way. Damage to the plants may result from too heavy browsing or trampling. In California the only serious trampling damage has been done by sheep. Sheep should be herded off newly seeded areas. Trampling damage by cattle has been light despite numerous cattle on some seeded areas. Their larger hooves do not damage seedlings as severely as the smaller, sharper hooves of sheep, but they may cause severe damage on light, loose soil or when the soil is muddy and the cattle sink in several inches.

Deer trampling has not been a serious problem in California, but Holmgren and Basile (1959) reported that it has been in Idaho. The difference is probably due to heavier deer concentrations on Idaho's seedings, steeper slopes, and lighter soils into which deer hooves sink deeply. There may be similar sites in California where deer trampling will be a problem.

Any grazing of bitterbrush seedlings during the first year or so is detrimental. If grazing starts in the seedling year and continues at a heavy level year after year, the plants will eventually be killed or will never attain sufficient size to contribute much to the forage supply. Protection of young seedlings is as important as earlier steps required to get the seedlings above ground. Therefore, livestock should be fenced out, rodents and jackrabbits controlled, and other needed steps taken to provide protection. On deer winter ranges, snow cover may give adequate protection to the seedlings. Generally, it is sufficient to protect the plants from all but incidental nipping for 3 to 4 years, provided they are grazed properly afterwards.

Insects

Cutworms (Lycophotia margaritosa) and wireworms (Elatridae) are the most serious insect threat to California plantings. There is no known way to forecast cutworm and wireworm damage before planting. Some method needs to be developed because treating with an insecticide runs around $1.80 per acre. Grasshoppers have not yet proved troublesome in California, but they have in Idaho. Grasshopper damage can be controlled by poisoning as prescribed by the Plant Pest Control Branch, U. S. Department of Agriculture.

Webworms and leafminers may occasionally kill a few seedlings but the damage is likely to be insignificant.

MISCELLANEOUS CAUSES OF SEEDLING LOSSES

Lack of soil moisture needs emphasis as a cause of seedling loss. Except on the very driest sites, removal of competing vegetation in site preparation reduces loss from lack of moisture to an acceptable level. Some, and probably many, of the seedlings that still do not make it are the naturally weaker individuals. The stronger bitterbrush plants, because of their rapid root growth, compete well with other plants starting to grow at the same time. But if a great many other plants are already established, they can remove the moisture before the young bitterbrush roots can grow.

Frost heaving may kill 1/3 to 1/2 of the young bitterbrush plants, particularly on sites with loam or heavier soils. Most of the damage occurs during the first winter after emergence; little is likely in subsequent winters. Frost heaving is particularly severe when the ground remains free of snow during most of the winter. There is no known way of reducing frost heaving losses.

High top-soil temperatures can kill young seedlings on light, granitic soils in the hotter regions of the bitterbrush range. The soil becomes so hot that it kills the cambium of the young stems. About the only way of combating this problem is by mulching or shading. So far, no practical methods of doing this have been developed.

Some seedling deaths are still unexplained. Many of these unexplained losses take place in early spring while the soil is still

damp, suggesting damping-off or attack by some other kind of soil fungus. Damping-off damage on bitterbrush seedings has never been definitely diagnosed in California, but has been suspected in several instances. Brown and Martinsen (1959) reported damping-off as a minor cause of mortality in Washington, and Holmgren (1956) reported extensive losses from damping-off in Idaho in the wet spring of 1953.

WHAT IS SUCCESS?

Planting success is judged by plant stocking. There must be enough plants to produce a meaningful amount of herbage. How many plants is enough? In northern California natural bitterbrush stands average 778 plants per acre; and the maximum stocking found by E. C. Nord was only 1,420. Most sites can support more plants. Grazing, fire, rodents, rabbits, insects, disease, and other factors combine to keep natural stocking below the capability of the site. These same factors will influence the final stocking density of plantings, but initial stocking should be close to the number the site can support.

Available soil moisture is usually the most limiting site factor. The amount available depends upon the amount of precipitation, the capacity of the soil to hold water, and the number and species of plants that invade a seeding and compete directly with the bitterbrush.

Too little is known about most sites to accurately assess all of these factors. Based on our experience, though, any site suitable for planting can support at least 500 bitterbrush plants per acre. Any fewer produce too little herbage to be worthwhile.

The upper stocking limit on one of the better bitterbrush sites in northeastern California is about 2,200 plants per acre. With denser stocking, the bitterbrush plants compete with each other for moisture and nutrients. Many are damaged and some die.

What does 500 to 2,200 plants per acre mean to the deer? Some idea can be gained by a hypothetical computation. We have found that it takes between 200 and 600 mature bitterbrush plants under proper use to feed a 100-pound deer for 1 month, assuming that it eats nothing but bitterbrush (fig. 12). This means that 500 plants will maintain a deer for .8 to 2.5 months. Maximum stocking of 2,200 plants per acre will maintain a deer for 3.7 to 11.0 months. Obviously, deer eat other plants, and since other plants invade seeded areas, the actual carrying capacity of a seeded acre is greater than the figures computed here. In addition, small acreages of seeded bitterbrush may enhance the range far greater than the amount of bitterbrush forage produced.

HOW MUCH DOES SUCCESS COST?

Seeding bitterbrush is expensive. But in considering costs we should again recognize that per acre values do not entirely reflect the values to the deer range as a whole.

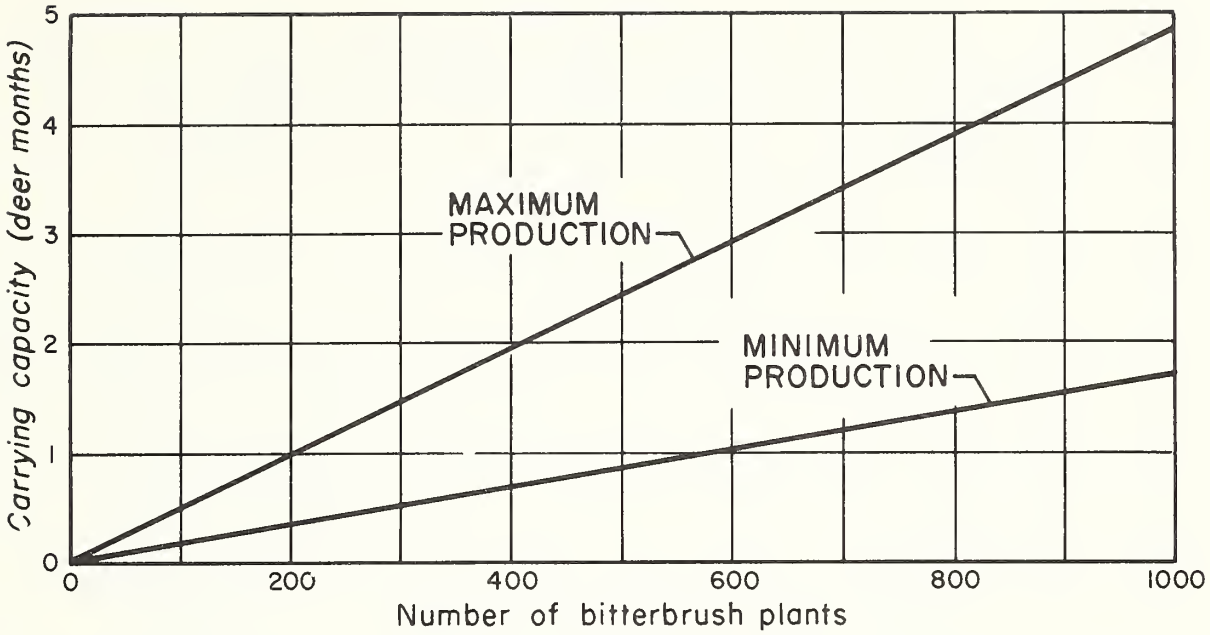

Figure 12. --Bitterbrush carrying capacity for a 100-pound deer in terms of number of plants.

Any kind of range seeding varies greatly in cost depending upon type of equipment used, size of planting, topography and amount of rock, efficiency of the operation, wages, and seed and material costs.

Equipment costs vary widely. For example, Pingrey and Dortignac (1957) reported a cost of $3.30 per hour for a D-7 tractor without fuel at mid-1950 prices in New Mexico. Fuel costs would bring this up to about $4.00. The Lassen National Forest's 1961 contract price for a privately owned D-7 is $7.60 without fuel or oil. Add these and the cost is about $8.34 per hour. The rental rate on a D-7 owned by the U. S. Forest Service is $10.40, including fuel and oil. Rates for other equipment vary as widely because of different assumptions for depreciation, life, and number of hours of use per year.

We have settled on the contract price of $8.34 for a D-7 and $5.37 for a TD-9 because we feel that this reflects the 1961 going price in northeastern California. Labor costs are computed at $2.68 per hour, the median rate for an Equipment Operator II in the U. S. Forest Service. Costs for plows, drills, rollers, and drags have been computed (Table 1), but you should not use these figures if they are not realistic for your operation. Estimates of time requirements for the various jobs and costs per acre have also been computed (Table 2); it is an easy matter to convert to any hourly charge you encounter.

Seedbed preparation with TD-9 or comparable tractor costs about $11.42 per acre (Table 2). This figure assumes that plowing, dragging, and packing are each done as a separate operation. This is a valid

Table 1. --Estimated hourly expense of equipment used in seeding bitterbrush

Equipment	Cost	Life	Use		Cost per hour of use			Equipment cost per hour	Fuel	Oil	Total cost per hour
			Per season	Total	Depreciation	Interest 6% [1]	Repairs				
	Dollars	Years	Hours					Dollars [2]			
Tractors											
TD-9 Int.	--	--	--	--	--	--	--	5.00	.23	.14	5.37
D-6 Cat.	--	--	--	--	--	--	--	7.60	.56	.18	8.34
Brushland plow	6,000	15	800	12,000	.50	.18	3/ 1.54	2.22	--	--	2.22
Rangeland drill	2,100	15	800	12,000	.18	.06	3/ .71	.95	--	--	.95
Roller	4/ 1,000	15	800	12,000	.08	.03	4/ 1.00	1.11	--	--	1.11
Railroad iron drag	30	--	--	--	--	--	--	(5/)	--	--	(5/)

[1] Interest calculated at 6 percent on 1/2 value divided by hours of seasonal use.

[2] 1961 contract price paid by the Lassen National Forest to private owners of equipment.

[3] Proportionate to costs reported by Pingrey and Dortignac (1957).

[4] Estimate.

[5] Negligible

Table 2. --Estimated costs per acre of site preparation and seeding bitterbrush on northeastern California deer ranges

Job	Equipment	Labor per acre	Equipment use per acre	Hourly equipment expense	Labor cost per acre	Equipment cost per acre	Total cost per acre
		--- Hours ---		------ Dollars ------			
Site preparation							
Plowing	TD-9 and brushland plow	.78	.62	7.59	2.09	4.71	6.80
Dragging	TD-9 and railroad iron drag	.31	.25	5.37	.83	1.34	2.17
Rolling	TD-9 and roller	.31	.25	6.48	.83	1.62	2.45
							11.42
Drilling	TD-9 and rangeland drill	.58	.40	6.32	1.55	2.53	4.08
Seed (3 lbs. per acre)		--	--	--	--	--	4.50
Thiourea treatment		--	--	--	--	--	.10
Endrin-Arasan treatment		--	-	--	--	--	.27
							4.87
Total							20.37

assumption because trying to do more than one job at a time with so small a tractor slows it up and makes the operation inefficient. Add $4.08 for drilling with a TD-9 and rangeland drill and $4.87 for seed and seed-treatment, and the total site preparation and seeding job comes to about $20.37 per acre.

This amount doesn't include equipment or personnel transportation costs, planning costs, or the crew's food or lodging, which vary a good deal from job to job. Nor does the $20.00 take into account protection from rabbits, rodents, insects, livestock, or big game, nonuse of the land, risk, interest on the investment, or taxes. It is only the cost of the physical job of preparing the site and seeding it, plus the cost of the seed.

There are several ways of reducing this cost. One is to use two brushland plows side by side behind a D-7, or comparable crawler-type tractor. Despite the higher hourly charge for the larger tractor and extra plow, this doubling up reduces the plowing cost from $6.80 to $5.22 per acre (computed from acre-time requirements reported by Pingrey and Dortignac in 1957). Another possibility is to use a large tractor and combine the plowing, dragging, and packing in one operation. This would reduce site preparation costs from $11.42 to $9.79; unfortunately, no hitch has so far been developed to permit pulling equipment behind the brushland plow, but this type of hitch is being developed under the auspices of the Range Equipment Seeding Committee, and should be available soon. Drilling costs can be reduced materially by pulling two rangeland drills side by side, or by using an inexpensive wheel tractor to pull a single drill where the country is fairly level. Again, these savings apply only to the actual field job. Some of them may be mere paper savings because of the added cost of moving extra and usually heavier equipment.

Where additional site preparation steps are necessary, the cost will obviously go up. Mechanical removal of standing, decadent bitterbrush or undesirable browse plants may cost as much as $12.00 per acre. Removal by controlled burning is cheaper but still an added expense.

Hand scalping and hand seeding takes about 12 man hours per acre (Holmgren and Basile, 1959). Seed costs are about $1.50 per acre. No costs are available as yet for planting with the Idaho adaptation of the Flexi-planter, the Hansen furrower, or the combination of these two machines now being developed. We can assume that the cost will be lowered by use of this type of equipment on sites for which it is adapted.

FIELD PLANTINGS OF BITTERBRUSH IN CALIFORNIA

The proof of research findings is how well they stand up in field application. From 1954 through 1962, 19 field scale plantings, ranging in size from 5 to 100 acres, have been made in California (Table 3). Initial stocking of bitterbrush seedlings have ranged from 0 to over

Table 3. --Field planting of bitterbrush in California

Area	Method of planting	Size acres	Time of planting	Initial establishment seedlings/acre	Survival as of 1962	Planting agency[1]
Hallelujah Jct. #1	Drill	8	F '54	388	Poor	CDFG, CFRES
Hallelujah Jct. #2	Drill	5.6	S '55	212	Poor	CDFG, CFRES
Red Rock #1	Drill	15	F '54	366	Poor	CDFG, CFRES
Red Rock #2	Drill	5	F '54	655	Poor	CDFG, CFRES
Red Rock #3	Drill	5	F '54	1,025	Poor	CDFG, CFRES
Red Rock #4	Drill	5	S '55	117	Poor	CDFG, CFRES
Red Rock #5	Drill	5	S '55	1,106	Poor	CDFG, CFRES
Flukey Well	Drill	18	S '57	11,887	Good	CFRES
Saddle Blanket Flat	Drill	60	S '60	1,200	Poor	Modoc NF
Doyle	Drill	10	S '60	100-200	Poor	CDFG
Doyle	Drill	17	S '61	349	Poor	CDFG
Doyle	Drill	30	S '62	100-200	Poor	CDFG
Cornell Rim	Drill	25	S '61	976	Fair	CDFG
Bolan Burn	Drill	72	S '58	575-3,750	Fair	CDFG
Pollic Burn	Seed spot	25.8	F '61	532	Good	Klamath NF
Pollic Burn	Seed spot	26.2	S '61	174	Good	Klamath NF
Spanish Spring	Drill	100	F '61	25,000-30,000	Excellent	BLM, CDFG
Longley Meadows	Drill	18	F '59	(2/)	--	Inyo NF
Tuolumne Rim	Drill	5	S '61	6,800	Good	Stanislaus NF

[1]CDFG = Calif. Dept. of Fish & Game; CFRES = Calif. Forest & Range Expt. Sta.; BLM = U. S. Bureau of Land Management.

[2]Trace.

25,000 per acre. Some seedlings emerged on 18 of the 19 plantings. The exception was at Longley Meadows on the Inyo National Forest--normally a very dry site and exceptionally dry the year of planting. Only 3.3 inches of precipitation fell between October, 1959 and June, 1960.

Initial establishment on 9 of the 19 plantings was over 500 seedlings per acre, the criteria for a successful seeding. Two, the 18 acre Flukey Well seeding in 1957 and the Spanish Spring seeding in 1961, were too densely stocked for the best growth of bitterbrush. Frost heaving during the first winter after emergence thinned the Flukey Well planting about 40 percent but left over 7,000 plants per acre--still well above the 2,200 plants per acre found to be maximum stocking for best growth and survival.

Initial stocking isn't, of course, a final expression of the success or failure of a seeding. The plants must mature if the planting is to be classed as a success. Rabbits have practically wiped out seedings at Hallelujah Junction, Red Rock, Saddleblanket Flat, and Doyle. At Hallelujah Junction and Red Rock it took the rabbits, with some help from cattle and deer, 4 or 5 years to accomplish this. At Saddleblanket Flat, rabbits alone wiped the seeding out in one year. Rabbits have also damaged the Cornell Rim seeding.

Cattle, with some help from deer and rabbits, are keeping the plants at Flukey Well closely hedged. If this close hedging continues, the plants will obviously never become large enough to produce a meaningful amount of feed for deer. The Klamath National Forest reports current heavy deer use on the Pollic Burn spot plantings.

These experiences emphasize the importance, already mentioned, of further study of ways and means of protecting and managing seeded browse stands.

SUMMARY

Browse seeding is a valuable tool for the game range manager. It is needed most on important deer ranges where the browse has been destroyed by overgrazing or fire. Bitterbrush has proved best for browse seeding in northeastern California. It is highly palatable, well adapted to most of the critical deer winter ranges, and withstands grazing well.

Research has found how to seed bitterbrush. The prescription varies from site to site but, in general, our recommendations for California are:

1. Seed collection. Collect seed from areas similar to the planting site. The period between the time the seed ripens and falls is short, making it necessary to keep close watch on seed development.

2. Seed treatment. Bitterbrush seed has a dormancy which must be broken by over-wintering in the soil or artificial treatment.

For spring planting, we recommend soaking the seed in a 3-percent solution of thiourea for 3 to 5 minutes.

3. Site selection. Two factors must be considered in selecting a site: Where do we need to plant? Where will bitterbrush grow? Plantings should be made where they are needed but not on areas where deer grazing is so heavy that the young seedlings are sure to be killed. Planting on such heavily grazed areas must be delayed until deer numbers are brought under control. The best guide to whether bitterbrush will grow on a site is whether it has grown there in the past. If this isn't known, soil surveys and other site evaluation are necessary. Bitterbrush should not be planted where the soil pH is above 7.3 in the top 5 feet or where drainage is poor.

4. Site preparation. Get rid of as much of the competing vegetation as possible, and prepare a smooth, firm seedbed. We recommend using a brushland plow, railroad iron drag, and large rollers.

5. Seeding. Plant the seed 1 inch deep on sites with soils which retain moisture well. On lighter soils, which lose moisture rapidly, plant the seed about 1-1/2 inches deep. The rangeland drill does the most efficient planting job. Mix 3 pounds of seed with 8 pounds of rice hulls to insure even seed distribution. Set the drill at 48 notches to seed 6 pounds of seed per acre. On some sites it is necessary to attach a roller behind the drill to firm the soil over the seed.

6. When to plant. We recommend spring planting on sites where spring precipitation is well distributed and the soil retains moisture well. On dry sites with light soils, fall planting is necessary.

7. Management of seeded bitterbrush stands. More is known about getting bitterbrush seedlings above ground than about what to do with them after they are established. Rabbits, deer, livestock, rodents, insects, high soil temperatures, fungi, frost heaving, and other factors all take their toll. Some can be controlled and some can't.

Between 500 and 2,200 established plants per acre constitute a successful bitterbrush seeding. Herbage production from 500 healthy, mature bitterbrush plants should maintain a 100-pound deer for about 70 days. A successful seeding isn't cheap. It costs about $20.00 an acre for site preparation, seeding, and the seed. The question is: which is more expensive--to leave deteriorated or burned deer range relatively unproductive, or bring it back into production?

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